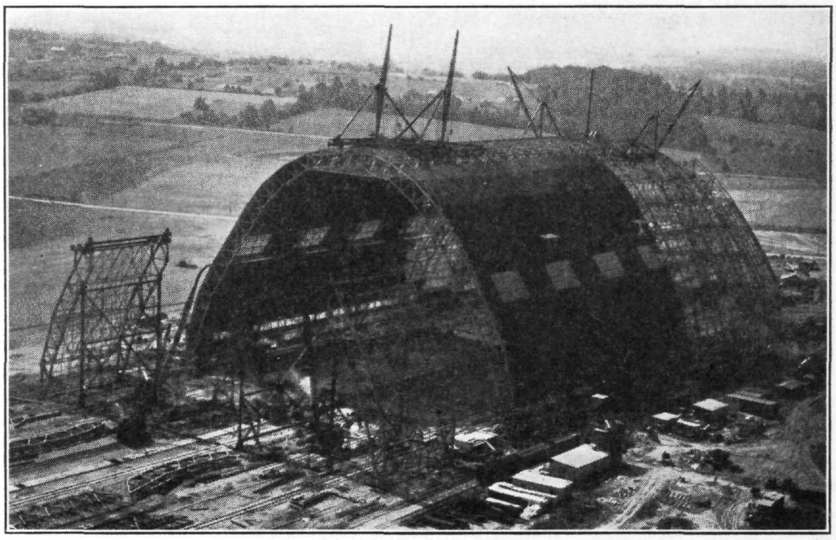
BUILDING THE WORLD'S LARGEST AIRSHIP FACTORY AND DOCK

By LLOYD S. HIGLEY, '29

The Airship Factory and Dock, built at Akron, Ohio, for the Goodyear Zeppelin Corporation, is intended for the construction and housing of the ZRS4 and ZRS5, the two super-zeppelins which are being built by this company for the United States Navy.

These airships will have a length of 785 feet, a diameter of 134 feet and a gas capacity of 6,500,000 cubic feet of helium gas, and will be the largest airships ever built. The building, however, has been planned to house an airship considerably larger than these now being constructed. It can easily accommodate an airship of 10,000,000 cubic feet capacity.



THE AIRDOCK NEARING COMPLETION
Note that construction started from the center. This is because center arch is fixed permanently and others are on rollers to allow for expansion.

The preparation of the site required the removal of 1,000,000 cubic yards of earth, which was used to fill in the low parts of the site.

The general level of the ground at the building site was about 1,038, referred to sea level. The soil consisted of about 2 feet of muck and 28 feet of sand, gravel and clay underlaid by solid sandstone, with a fairly level surface. As the water level was about 1,036, with little chance for drainage below this level, it was deemed best to remove the two feet of muck from the site of the building and fill in with about six feet of selected gravel and clay from the adjacent hillside, which was deposited in nine-inch layers and rolled.

The substructure work consists of concrete footings for the arches, carried on vertical and inclined concrete piles driven to rock, concrete ties across the building laid on the sand and clay after removing the muck and heavily reinforced to take the thrust from the arches, concrete door circles for supporting the rails carrying the doors which are also carried on concrete piles, a concrete service tunnel the full length, and one-half the width of the building, and lines of concrete docking rails supports. The piles number about 1,300 and carry maximum loads of 30 tons each.

This building is approximately a semi-paraboloid in shape, that is, sections taken across it form parabolas, and its longitudinal section also forms two half parabolas connected by a straight line. The length is 1,175 feet between center lines of door tracks; its width 325 feet center to center of arch pins; and its height 197.5 feet from center of lower to center of top pins. The height from the floor to the platform at the top is 211 feet. The floor area is 364,000 square feet, the largest single uninterrupted floor area yet covered. The volume is approximately 45,000,000 cubic feet.

The original Zeppelin shed at Friedrichshafen, Germany, built in 1908-9 is 603.5 feet long, 150.8 feet wide and 65.6 feet high. Later a larger hangar was built, having a length of 787.2 feet, a width of 150.8 feet, and a height of 114.8 feet. These hangars, and most others built in Europe, are of structural steel arches, with sliding doors at the ends.

The largest hangars so far constructed in the United States are those at Lakehurst, N. J., and at Belleville, Ill. The former has a length of 803 feet, a span of 264 feet and a height of 172 feet to the upper pin. It is intended to house two large ships. The latter has a length of 810 feet, a span of 150 feet and a height of 150 feet.

All of these hangars have vertical doors that open horizontally, from the center outward.

Perhaps the most difficult part of airship operation is the launching and docking of the ship, and it is essential that the air-dock should cause the least practicable interference with normal wind currents, in order that the launching and docking operations may not be complicated by cross currents created by the building itself or by the open doors. It is this consideration which suggested the shape of the Akron airdock.

Hangars of similar design to the one being built at Akron, although smaller, have been built and operated at Dresden and Liegnitz, Germany.

Before starting the design of the Akron building, Dr. Karl Arnstein, director of engineering of the Goodyear Zeppelin Corporation, who proposed the use of the parabolic design at Akron, had extensive tests made on a model of this shape in the wind tunnel of the Daniel Guggenheim School of Aeronautics of New York University. The model was about 1/240th of the size of the completed building. These tests demonstrated the superiority of this shape building in offering minimum resistance to wind currents, and also furnished valuable information in regard to the magnitude and distribution of the suction forces caused by the action of the wind on the surface of the building.

The wind, as is well known, when meeting an obstruction, such as a large building, is deflected upward and often creates a partial vacuum over the upper parts of the building which cause a suction tending to force the roof of the structure outward, instead of inward. This suction force often occurs, and even reaches its maximum intensity, on the windward side of the structure. In magnitude, these suction forces may be several times as great as the directly applied wind pressure.

Dr. Arnstein recommends that the suction or outward pressure should be taken at three-fourths of the exterior. His experiments indicated that the outward force should be assumed at not less than one-half the inward, with provision for securing roofing against local outward forces equal to the full direct pressure. American practice in designing buildings to resist wind pressures has heretofore neglected the importance of these suction or outward pressures. Observations on air currents at the Lakehurst hangar have demonstrated that the currents around the open doors (sliding type) may obtain a velocity twice that of the prevailing wind.

As it is desirable that airships should head into the wind when landing, the longitudinal axis of the hangar should coincide with the direction of the winds prevailing during flying weather. For the location selected, it has been found that the proper orientation is north 30 degrees east.

The general design is carried out along lines originally proposed in the stress analysis department of the Goodyear Zeppelin Corporation headed by Mr. Helma. This general design was selected not only because of its areodynamic advantages, but also because it proved to be economical in weight of steel. Mr. Helma in his studies also suggested the system of vertical and horizontal trusses placed between the upper and lower chords of the arches instead of the system of bracing in the planes of the arch chords as ordinarily used in this country. This system is known abroad as the Dietz System of bracing.

In general, the structural design consists of eleven parabolic arches spaced 80 feet 0 inches on center and connected by the system of vertical and horizontal trusses above mentioned. In addition to forming the bracing system for the structural shell, these trusses carry light trussed rafters spaced 10 feet 0 inches on center and on these are placed the Z-bar purlins 8 feet 0 inches on center. At each end of the main shell are placed two diagonal arches, meeting the end arches at the pins, which are 800 feet apart. The doors are built up of similar arched and braced ribs. All material is structural grade steel except the chords of the main arches, which are of silicon steel. The horizontal component of the thrust from these arches is taken up by reinforced concrete ties placed under the building.

One of the unique features of this design is the entire absence of all expansion joints. The center arches are fixed in position, while all others are carried on rollers, placed transversely to the axis of the structure, allowing it to expand freely as a whole, from the center to each end. This allows the end arches, supporting the upper door pintles or hinges, to move laterally about four inches under the maximum range of temperature, a motion which is taken up partly on the pins themselves and partly transmitted to the doors, and absorbed by the deformation of the door frames.

In order to reduce the lateral motion of the upper pins under wind loads it was decided to convert the three-hinged arches into two-hinged by riveting up the lower chords after the erection of the steel.

"ORANGE PEEL" DOORS

The most unusual and unique feature of this building is doubtless the spherical doors, with their hinges and supporting trucks and operation mechanism for opening and closing them.

If one can visualize a quarter of a half of an orange peel set up on a flat surface, held with a pin at its pointed top and resting on a set of rollers distributed under the bottom edge and imagine this one-eighth of an orange peel as 202 feet high, 214 feet wide at the bottom, fastened or hinged at the top point with a huge hollow forged pin and resting on 40 wheels at its base, he would have an idea of what one leaf of two that close one end of the hangar is like. The doors alone weigh about 600 tons for each leaf or 1,200 tons for each end of the building.

It is especially desirable that the floor of the dock and the yards in front of it should be as nearly level as feasible, since men handle the ships by hand with ropes as they are docked and launched. Anything projecting above the level in front of the dock would be a stumbling-block to the men.

As this building is primarily a factory for the construction of airships, it is equipped with a considerable amount of mechanical handling de-

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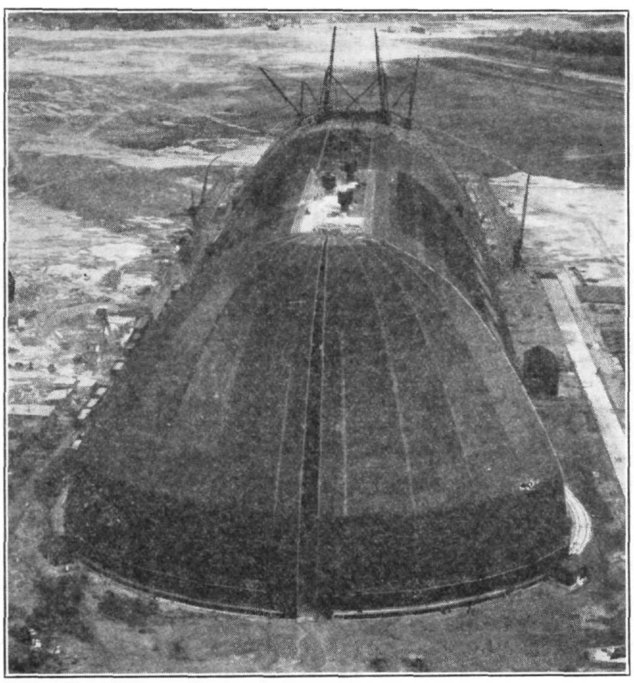

THE COMPLETED AIRDOCK

AIRSHIP FACTORY AND DOCK

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vices. At the center of the building, overhead, there is a single crane runway consisting of a 12-inch I-beam supported on trusses. This runway will carry a six-ton electric hoist for handling material.

At each side of the center are two 12-inch I-beams designed to carry working platforms which can be lowered and raised to any desired height, and on which the workmen engaged in assembling the ship's structure are employed.

Further down the curved sides of the structure are more I-beams for carrying additional working platforms.

At the center of the structure there is provided a fixed working platform the full length of the building; and at various levels, six on each side, are catwalks two feet wide, also running the full length of the structure and located between the chords of the arches. Access to the upper platform is provided by two stairways, one on each side of the building near the center, and by a specially designed inclined railway, intended to transport men and materials to the upper levels.

The engineers consider it useless to attempt to heat this structure. The offices and shops are heated by independent gas-steam radiator units, and electric heaters will be used on the floor and on the working platforms in cold weather.

Only a very small amount of natural light is provided, and all operations will require artificial light. There were three reasons for doing this: First, the fact that assembly would probably require continuous work, day and night; second, the difficulty of making skylights water tight and the cost of any good skylights; third, the fact that even with ample windows, much of the work would need to be done by artificial light owing to the interference of the assembled ship with the light from the outside.

The general lighting consists of adjustable projectors of 1,000 watt capacity each, located along the catwalks, from 65 to 150 feet above the floor, and seven lines of outlets along the catwalks and upper platform. Additional lighting is also provided at all stair and hoist landings.

The operations of getting a large airship in and out of the dock require great care, as injury to the ship would result if it were to strike any part of the building. The German practice has been to use, for this purpose, cables attached to the ship's hull at certain fixed points and to trolleys which run on fixed tracks, one on each side of the ship. These trolleys are operated by hand, and the ropes are held by quick-release levers, so that any undue strain can be quickly relieved by releasing that cable. The tension on these cables may amount to over five tons pull on a single rope.

As the airships now being built at this plant will use only Helium gas, provision for this gas only is being made. To receive this gas, there will be installed a storage plant consisting of about 100 pieces of 24-inch gas pipe, each piece having a length of 80 feet, and closed at both ends with forged and welded heads. The pipes are slightly inclined, the upper end being connected with the gas manifolds; to the pump and to the gas cells, through the service tunnel; the lower to water lines which are used in giving the system its initial charge of helium and in discharging when a total discharge is necessary.

AUTHOR'S NOTE

The author obtained the material for this article by personal observation and from Dr. Arnstein's lecture. Pictures are published through the courtesy of The Goodyear Zeppelin Corporation, Akron, Ohio.